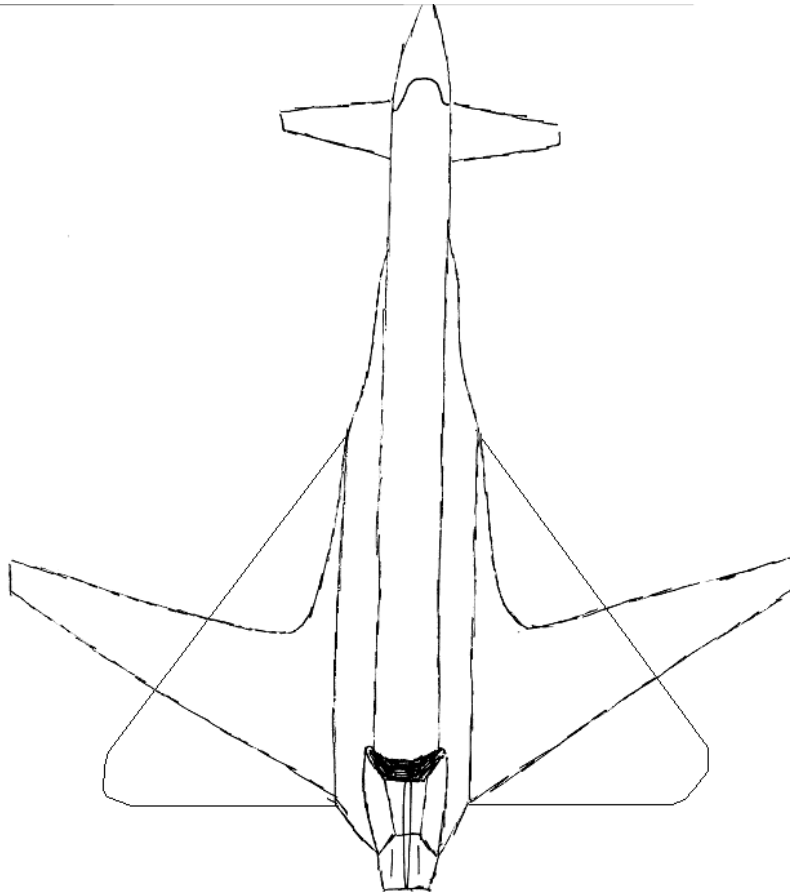


Next Generation Super Sonic Airliner



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Introduction

A crack is heard off in the horizon. People on the ground, tilt their heads and look up. Far off in the distance, a triangular shaped aircraft can be seen descending and preparing to land. The landing gear extends as it glides over the numbers. Its nose pitches up at a seemingly drastic angle caused by its unique delta wing. The wheels touch the pavement releasing a cloud of smoke into the air. Air spoilers combined with heavy braking prevent the slender aircraft going off the end of the runway. Inside, the passengers are delighted in ease and shortness of the trip. Only three hours ago, they were in London, and now they have just landed in New York.

This was the Concorde, the only passenger supersonic airliner to enter airline service to date. It was an amazing piece of technology, capable of speed surpassing Mach 2. It was the pride of the British Airways and Air France for over 25 years. Unfortunately, the 14 active passenger aircraft were pulled out of service after a fatal crash in France. Before the crash, the Concorde had the best safety record of any aircraft in the industry, now, its remains lay strewn over Gonesse, France. A crash report suspects the cause was attributable to a strip of metal puncturing the tires. This caused a blow out, which ruptured the fuel tanks on takeoff. Flames engulfed the plane, and the aircraft was lost. This single accident was the beginning of the end of the Concorde, and the dream of a super sonic airline.

Mission:

An ideal next generation super sonic would mimic the Concorde in flight performance, but need a substantial improvement in fuel efficiency and reduced operating costs. This can be accomplished with a

myriad of new technologies, some aimed at the aerospace industry, others not. But in order to succeed, we need to address all the downfalls of today's seeming plagued airline industry, and should incorporate the technologies of comparable super sonic military applications. Environmental and noise factors will also have to be evaluated in the design of super sonic aircraft, presenting unusual hurdles that will need to be conquered.

Wing Design: Flying Fast, Then Slow Again:

In order for an aircraft to reach mach speeds, the airfoils and wing layouts need to be designed specifically to reduce drag and boost performance. For this particular application, a delta wing will be utilized during cruise speed. A delta wing allows for excellent high-speed performance and efficiency¹⁶. Although this technology is not new (patent was first filed 1867), its benefits in high speed applications have been exploited in recent years with advanced air superiority fighters².

These airfoils are unique as they look like triangles when viewed from the top. The leading edge is tapered as much as 60 degrees back and the trailing edge usually meets the fuselage at 90 degrees¹⁶. Delta wings have short wingspans, which help lessen the affects of sonic booms in flight¹⁶. They also reduce the aircrafts overall profile drag¹⁶. Delta wings are great and simple platforms for high speed cruises, but problems tend to plague these aircraft when they approach the lower speed end of the flight envelope.

Delta wings become unstable at slow speeds due to very high stall speeds¹⁶ While some pilot may be comfortable with high landing speeds, most are not. Most airports don't have the facilities to accompany such designs, as they require monstrous amounts of runway⁴. Some delta wing applications have computer based flight controls, flaps and trim systems that allow for slower speeds, but these "systems are sources of tremendous drag" and still make for "hot" landings¹⁶. The overall design of a delta wing make it pitch up at a sizable angle during slow speed flight, reducing forward visibility¹⁶. This was a noticeable trait found on the Concord.

To assist the concept aircraft with slow flight, we will use the morphing wing concept to its full potential. When the aircraft is in sub-sonic flight, the wings will morph into long, slender, forward sweeping wings. This will drastically reduce the stall speed and increase the lift factor. The forward sweeping wing is unusual, but proven to be successful through NASA test programs and applications (the NASA X-29). It is also the easiest design for a delta wing to morph into, as it requires the fewest change and would not require ballast because it would be able to retain a similar center of gravity¹⁶. With that said, it still requires a drastic transformation of the entirety of the wing and airfoil compared to past swing wing designs (Fb-111 and F-14 Tomcat).

Slow speeds are relied upon over pilots performance while landing. This not only makes the landing safer and easier, but also allows for use of shorter runways, allowing the aircraft to operate out of a greater number of airports⁵. In order to allow aircraft to explore this slower realm of flight, and entirely different airfoil and wing design will be needed. This would allow the aircraft to land at fields with runways less than 10,000 feet in length. In order to do this, we will literally need to change the entire wing in flight. This may seem impossible, but this is exactly the design concept I plan on employing. The solution lies within the infant field of nano-technology.

The use of nano technology to modify airfoil and wing designs in flight is a revolutionary idea being explored by NASA. NASA's wing morphing technology is still untested in manned applications, but yields promising results. Design concepts use electro based polymer actuators controlled by sensors hooked up to a computer²¹. The sensors record pressure data, which the data interprets and transmits a command to the nano actuators²¹. The actuators respond accordingly, modifying the wing for optimal performance. This would allow the concept aircraft to transition from a takeoff configuration (high lift, slow speed) to a supersonic cruise configuration (delta wing). This technology is known as wing morphing by those who have begun to develop it into more advance forms. The idea of changing the physical shape of the wing in order to boost low and high-speed performance is really nothing new.

Aircraft such as the FB-111, F-14 tomcat and the B-1 have swing wings, which swing forward for improved slow speed handling, then back to form a delta wing for high speed performance².

Such technology could also be harnessed to eliminate control surfaces. On a normal aircraft, hinges and gaps between the control surfaces are sources of substantial drag as air slips between them⁴. In order to reduce this, designers use gap seals to smooth out the air passing over the wing. These add weight and complexity and aren't completely effective³. A morphing wing could morph the tips of each wing in directions in order to maneuver the aircraft. They would be more efficient, as they would have more effective travel and shapes, and no gaps allowing for drag or airflow disruption.

Due to the size and speed of the concept aircraft, special technologies would have to be applied to slow the aircraft. On conventional aircraft, this is done with various combinations of speed brakes, flaps and spoilers^{4,5}. With the morphing wing, all these technologies could be programmed into the movements of the wing. The trailing edge of the wing could be drooped like flaps. Ridges could be programmed to be shapes along the wing, temporarily disrupting airflow, creating drag and destroying lift, all key to slowing a "slippery" aircraft (an aircraft that is hard to slow because it lacks substantial drag⁵).

Other benefits would be seen in a drastic reduction of parasite drag. On a semi-monocoque aircraft design (a structure built with a partial load bearing skin re-enforced with ribs and bulkheads⁴), each and every little rivet is a source of drag. Multiply that by 40,000 rivets, and your drag is substantial. A morphing wing would be similar to a composite wing, where there are no rivets, thus reducing drag.

In order to make a more stall resistant aircraft, a small set of canard wings will be utilized forward the morphing delta/ forward swept wing. This technology is the most primitive of all powered flight, as it was the configuration of the Wright flyer². The canard has been successfully used on modern applications such as the Rutan Long Eze and Beechcraft Starship². They provide a double lifting surface, where both the wing and the horizontal stabilizer provide lift⁴. On a conventional configuration,

the horizontal stabilizer provides a downward force on the tail. The camber on the wing makes the aircraft want to pitch down, and the stabilizer compensates for this motion. This degrades from performance⁴. This is not needed on a canard, allowing for better loads, higher speeds, and improved efficiency over comparable designs.

With the obvious benefits of a morphing wing comes a list of shortcomings. On a standard commercial airliner, the fuel is stored in the wing and away from the passengers¹⁴. With the wing structure constantly moving, there is little room inside the wing that could safely be used and resist failure. This means the fuel has to be stored closer to the passengers, which is undesirable for crashworthiness. The solution is to have a section of the wing be made of solid-state composite materials, which would make up the better part of the wing root. This would attach directly to the fuselage, but would still provide a margin of safety for the passengers. These would be faired to provide minimal drag at cruise speed. For the limited space inside of the morphing wing, rubber fuel bladders would be used. Granted it's an old technology (used since World War Two on B-17s to mend shot up fuel tanks²), it would be an ideal application. They would allow for movement as long as the area in which the bladders were stored was not compressed.

The composite wing root will also play host to the landing gear. They will be trail link gear with 6 wheels per truck. This will disperse the load among the tires, preventing blowout as seen on the Concord. Smoother landings and less component wear would also be a desirable by-product of this application. Trailing gear is a common gear layout seen throughout the industry, and has a proven performance record. By using it on next generation aircraft, it will simplify the maintenance and allow for lower development costs.

When landing at high speeds, friction brakes wear out easily and create a lot of heat (and once in a while a nice pyrotechnic display⁵). Wear necessitates their replacement quite often⁹. In order to solve this problem, the concept aircraft will use magnetic brakes. This technology is primarily used on extremely high-speed land vehicles in order to slow them down. It also eliminates problems with

hydraulic failures and leaks. Such problems can lead to dramatic ground loops, and overshoots attributable to failed brakes. A magnetic system would help prevent these problems and reduce weight. They are ideal, as they produce no friction, and are low maintenance. They work by applying opposite magnetic fields between a rotor and a magnet⁶. As they get closer, the field's influence on the rotor and wheel becomes stronger, slowing it⁶. In turn, the aircraft is slow with no friction. The entire system would need to be designed to avoid interfering with the aircraft's compass. The magnetic fields produced could possibly be used to help recharge the battery, minimizing the field.

Fuselage

The ideal fuselage for any high-speed application is a thin, long slender fuselage⁷. This commonly seen layout reduces speed depleting drag and because of its low profile drag, and a tubular shape make it extremely strong. The fuselage will be constructed with composite materials. Using any type of composite is beneficial to aircraft design because it allows for complex curves and shapes that simply cannot be achieved with comparable aluminum alloys¹¹. Composites can also maintain their strength despite drastic curvature.

A major problem with today's fleet of semi-monocoque aluminum airframes is fatigue. Fatigue is when the metal cycles through thousands of small movements caused by vibrations, pressurization and decompression⁵. Basically, the metal forms thousands of tiny stress cracks, which will lead to an eventual catastrophic failure of that component. Composite materials are less prone to this problem, but they still suffer from UV deterioration (sunlight can cause the fiberglass to degrade), delamination (separation of fiberglass layers) and stress cracks¹¹. These stress fractures can build up rapidly with an aircraft that is regularly stressed to close to a component's critical failure point (the point in which the composite structure completely fails¹¹). Stress failures in composites are sudden, whereas aluminum deforms before it fails.

In order to solve this problem, this aircraft will use a new technology based on carbon nano tubes. The carbon nano tubes can be imbedded in the composite structure, forming a solid matrix of

these tubes (which can also allow for an electrical current to pass through them²³). Computers can analyze the resistance of the carbon nano tubes throughout the structure. When a stress crack forms, the connection will be broken, and the computer will be able to determine exactly where the trouble area is located²³.

It 's always great to know as the pilot that your aircraft maybe forming weak spots and stress fractures in its structure during flight. But what are you suppose to do about it while you are cruising at 50,000 feet? That's the biggest benefit of carbon nano tube technology. It allows for a "self healing composite" while in use. As previously stated, the computer can detect exactly where a stress fracture occurs. To fix this crack, the matrix of carbon nano tubes will be charged with electrical current, creating heat²³. Composites are typically cured with heat¹¹. This means that an extra repair resin can be designed in to the wing structure, so when it is heated, the composite resin will melt, then cool, filling and fixing any developing stress fractures.

Another advantage to composites is that different types can be utilized on throughout the airframe yet still be one piece¹¹. For example, the leading edges and nose section are prone areas for friction heating, or heat caused by rapid movement of air over a surface¹. To reduce the effects of heat on the airframe, a composite design with a high ceramic ratio can be utilized (the ceramic will shield the structure by absorbing and dispersing the heat. A good example of this can be seen with the space shuttle's heat absorbent tiles²). Ceramics would also be beneficial if used in the engine compartment. This absorbs and disperses the heat better than a carbon fiber or glass composite¹¹. But ceramics are heavy and brittle, so for stress bearing areas, a carbon nano tube structure will be utilized¹¹.

A key element in the design of the aircraft will be the airframe shape and how it is affected at supersonic speeds. There is a concept that has been applied to all supersonic aircraft since it's discovery in the 1950's. It's goal in to minimize the formation of shock waves over the airframe that are attributed to super sonic flight¹⁶. The *area rule* concept allowed for beneficial drag reduction (up to 60%¹⁶) at super sonic speeds. Basically, the aircraft needs to maintain a "smooth distribution of area in the

proximity of the airfoil”¹⁶. This means that for every bulge in the aircrafts fuselage (canopies, wings, intake cowlings ect.) there must be an indent to evenly distribute the area.¹⁶ The use of composites will make it easier to form these curbs to an idea shape.

In order to lower maintenance costs, all major systems on the aircraft must be easily accessible with minimal hassle. The best way to do this is inspection plates on the exterior and interior of the aircraft. Remove able panels along the belly of the aircraft would allow access to lines and system running under the passenger and baggage compartments. This prevents the need to remove all the seats to address problems in that area. However, the more exterior panels you have, the more parasite drag you get from latches (parasite drag ¹⁶) and it’s more likely that a panel might part company with the aircraft during flight. For systems and lines running on top of the passenger compartment, the ceiling panels would give direct access to trouble areas. The majority of the systems would be accessible through the ceiling to minimize exterior disturbances. This way there will not be exterior panels on the top of the aircraft; and passenger safety would not be directly compromised (decompression) if a panel were lost from the belly.

The Front Desk:

The cockpit area will be completely separate from the passenger compartment. This would be a solution to recent cockpit intrusions and hijacks. The two-person crew (first officer and captain) would be seated in this area, which will have all necessities (lavatory, sleeping and food). The panel would be integrated into visors similar to many military applications (Apache helicopter). This would maximize situational awareness as the pilot could look out the windshield and still be able to read the flight information at the same time. All readings for flight like airspeed, climb, weather and navigation would be displayed along with an artificial horizon lining up with the true horizon. All flight up coming obstructions and traffic would also be viewable through the visor, so adequate time may be available to make changes to flight paths. This would help re-enforce the rule of 90% of the time flying you should “have your head outside” the cockpit. All radios will be placed in a center console located between the

pilots for easy access. Should this system fail, a glass panel displaying all flight information and engine information will be placed between the pilots with a similar layout to helicopter panels¹³. This redundancy will help insure situation awareness in emergency situations.

Underneath the cockpit will be the nose gear. Tricycle gear will be utilized because of a proven safety margin and ease of operation⁴. Tricycle gear is not as prone to ground loops and nose overs as comparable conventional gear⁴. It is also not as cumbersome in cross winds⁴. This helps make it easier for the crew to land the aircraft, despite the environmental conditions (bad weather).

It's All In the Thrust:

The true trick to achieving supersonic flight is the power plant. The earliest super sonic aircraft used troublesome rocket power plants accompanied with Short range (Bell x-1)¹⁶. This made the pilots proficient glider pilots, as the aircraft had to glide back to the airport. These were also extremely dangerous, as the rocket fuel was explosive². Afterwards, jet engines were used to achieve mach numbers. They did it safely, but were incredibly inefficient on fuel. This was one of the downfalls of the Concorde, and could easily scrub plans for aircraft today with rising fuel cost and higher consumption.

For this concept, two different types of engines will be designed into a single hybrid engine. For the take off and low level operations, twin turbo fan engines, similar to the CFM56-7 series found on newer Boeing 737's will be used². These are the latest in a generation of slightly more efficient and much more powerful engines². Turbo fans are more fuel efficient because a compressor provides for a higher compression ratio, which makes for better fuel economy when compared to early jet engines¹⁴. Other than efficiency, they are also much more quiet than comparable engines¹⁴.

The turbo fan engines will be used to get the aircraft up to speed and altitude, but for cruise, a more efficient, high-speed engine will be needed. Enter the variable cycle engine. This is a hybrid turbo jet engine and ramjet¹⁹. Ramjets are lightweight, high speed engines that produce high thrust, but they have a low compression ratio (about 2: 1), which means terrible fuel economy¹⁷. So to help the pathetic

fuel economy, a turbo fan configuration will be added to help compress the gases in the engine. This will raise that critical compression ratio¹⁹. The entire configuration is very similar to current military aircraft engines, and is a similar concept to what was used on the SR-71 Blackbird (capable of mach 3)². The variable cycle engine will be used for cruise, and then turned off to save fuel and reduce noise during low level operations. Another way to try to increase fuel efficiency would be to attempt a pulsing fuel injection. This means that instead of a constant flow of fuel to the combustion chamber, fuel will be added intermittently, much like a pulse jet engine¹⁸. Without fuel constantly being dumped into the engine, the fuel economy goes up.

The benefit of making a hybrid of two different types of engines is the efficiency one achieves at different points in flight (takeoff, cruise, landing). Using a turbo fan engine is also highly beneficial on initial takeoff and climbs, as it's lightweight does not hinder performance. The two engines, for redundancy, would all be located in the tail to allow for proper weight and balance (delta wing C.G is located farther aft than conventional aircraft)¹⁶. A double firewall would separate the passengers from the engines and any problems. In the event of a fire, there is no material aft of the engine compartment to burn, reducing the risk of complete destruction or the forward spread of the fire while in flight.

All three engines would have a single air inlet, which will provide the air to the engines. To minimize drag when the other two engines are shut down, the airflow to those engines would be cut off by means of hydraulically operated door type fairings. This adds complexity, but the aircraft would benefit from a drastic reduction in drag, and reduced component wear induced by air passing through the inactive engine. This single engine cowling would represent a significant reduction in drag when compared to other aircraft with a separate cowling for each engine.

Safety refinements

When experimenting with new technology (wing morphing) emergency design refinements need to be incorporated into the entire design to accommodate. Failure of electrical system would directly affect the morphing wing. Redundancy is the solution. Multiple sources of

electricity and back up batteries, generally old school technology, would be utilized. But there has been failures of electrical systems even with all of these safe guards in place.

To counter such occurrences, ram air turbines (**RATs**) can be used after the aircraft has slowed to sub-sonic speeds. These are used on the current fleet of airlines, but would prove ideal as yet another redundant system. The system evolved from similar air power generators used since the pioneering age of aviation²². These systems rely on airspeed to spin a propeller blade directly attached to either a hydraulic pump or an electric generator²². They are able to provide emergency power for the landing gear, flight control systems, and most importantly, the morphing wing. An ideal location would be in the composite wing roots, where they would be exposed to airflow but not be a huge drag component. During the event of an emergency they will automatically deploy or can be deployed by the crew. The RAT system was recently seen in action during the emergency landing of an Airbus300 in the Hudson River. They provided the crew with the emergency electric power and hydraulic pressure to ditch the aircraft²².

Keep the neighbors happy:

A key to airlines and airport operations is to keep noise pollution to a minimal. Most pilots love the sound of an aircraft-passing overhead, but as far as our neighbors are concerned, the noise is annoying. Noise is the biggest factor during the landing and takeoff stages of a flight, where the aircraft are in high drag or lift setting with flaps and gear extended⁴. The morphing wing design will reduce the sound produced by gaps found between moving components, such as flaps, ailerons and elevators²¹. Since it is a one-piece application, these wing gaps are non-existent. When the landing gear is extended, the resistance to airflow produces a substantial amount of noise. The solution is to fair the gear so when they are extended, they will be more aerodynamic, thus making less noise.

Sonic booms can also be troublesome. An innovative solution has been in development by NASA in order to reduce there sound. A telescoping nose has been tested as a possible means for reducing the sound produced by an aircraft traveling at a super sonic speed. The idea of the concept is to

break up the sonic boom in to a couple of smaller booms, which are less perceivable from the ground, but still exist²⁰. This would remodel the sonic boom and reduce the sound significantly compared to aircraft like the Concord.

Most jets are almost defined by the streaking sound made when the engine releases hot compressed gases. In order to change this, designers must analyze how the exit exhaust nozzles are designed. Even minor changes in the design of the nozzle can have drastic affects on the sound of an aircraft¹⁸. A simple solution can be found on the United States' most advanced stealth bombers. Obviously, an aircraft is not stealth if you can hear it coming. So the military had a diffuser (basically a plate or airfoil) extend from below the nozzle of the engine¹⁰. This directs the noise upward and away from the ground¹⁰.

In conclusion

In order for the airline industry to make a transition into supersonic flight, designers need to step up and meet the challenges set fourth by reliability demands, government regulations and flight performance challenges. This means incorporating various forms of comparably infant technologies, which no company likes to do all at once. Such an attempt would require extensive funding in order to meet the standards of the FAA.

This hurdle should not deter companies and private contractors. If the airlines truly want a supersonic aircraft, it can be done. The advantages of the capability of supersonic passenger transport would provide a kick-start to today's dated airline fleet. It is time that we work to reduce cost of air travel, and all of the negative ideals that accompany it. Quick transportation would allow pilots to fly more trips year, producing more income, and would allow for a higher passenger rate. Such benefits would help ease the problems with delayed flights and save on costs. The next generation of airlines must be capable of super sonic flight, or the cost of operating an airline may no longer be justified by the profit, communication, transportation, or environmental benefits.

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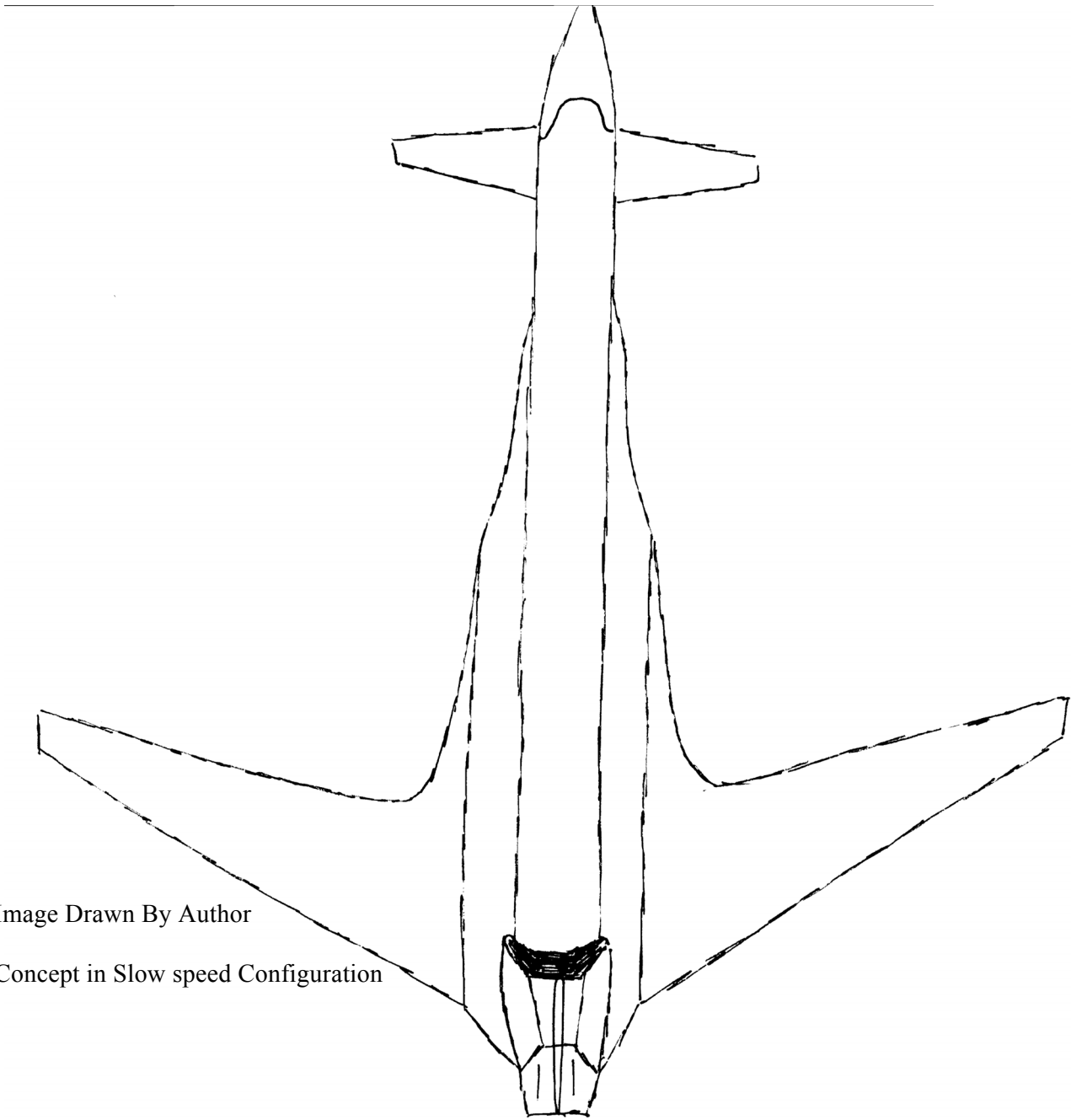
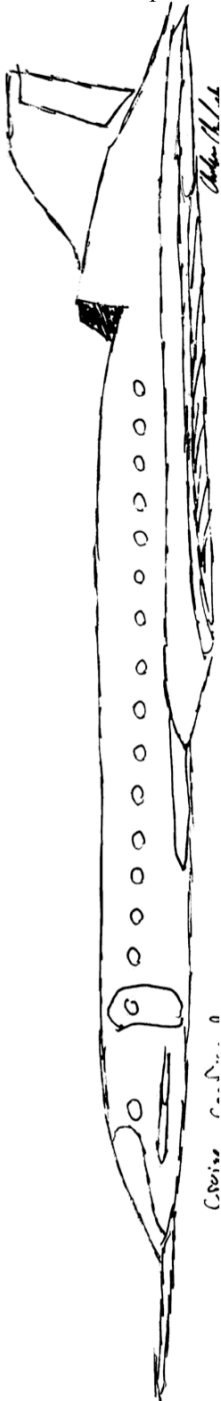


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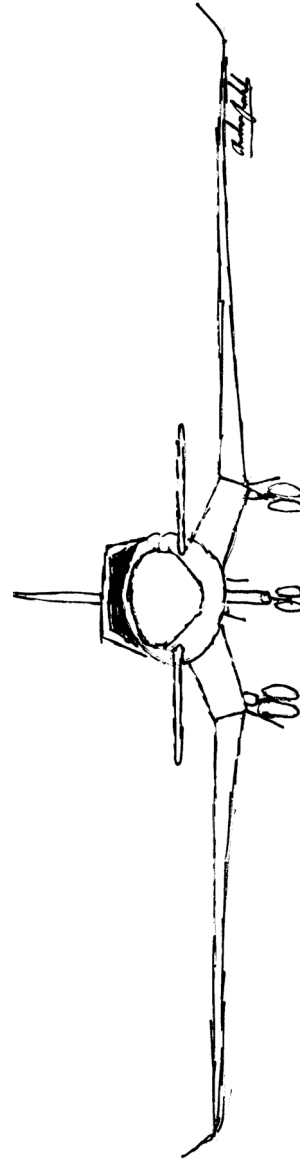
Concept in Slow speed Configuration

Images By Author

Side View of Concept Aircraft



Forward View Landing Configuration



Concept Aircraft in Cruise configuration

Image Drawn By Author

